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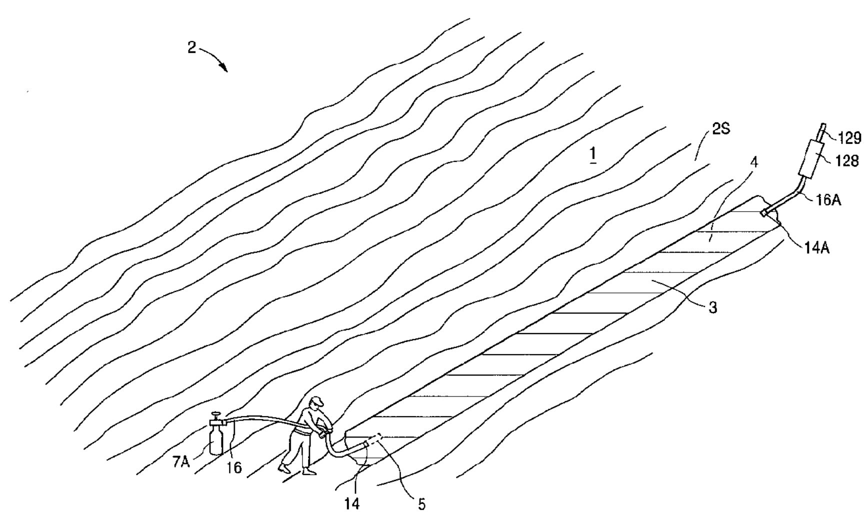

(57) Abstract: A phytotoxic gas is injected into a treatment space (4) between a soil surface (2S) and an impermeable or semi-permeable membrane (3) to weaken and/or kill plants (28) such as weeds, algae, and fungus growing on or from the surface (2S) of the soil (1). A gas injector (5) is used to inject the phytotoxic gas from a gas supplier (7A) into the treatment space (4). In one embodiment, a single injector (5) is inserted between the soil (1) and an impermeable or semi-permeable membrane (3) and the atmospheric pollutant containing gas disperses from this single injection point throughout the treatment space (4). In another embodiment, a conduit (5) or lattice arrangement of conduits (16) is used to inject the atmospheric pollutant containing gas uniformly into the treatment space (4). In accordance with this invention, the plants (28) are exposed to a sufficient concentration of the phytotoxic gas for a sufficient period to weaken and/or kill the plants (28).

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METHOD AND SYSTEM FOR WEED CONTROL

BACKGROUND

Methyl bromide is a chemical applied prior to planting to kill undesirable plants in the soil. Methyl bromide destroys living cells of undesirable plants and their seeds once it is transported across their cell walls. Currently, methyl bromide is being phased out of use due to its deleterious effect on the ozone layer and human health. Thus, a substitute for methyl bromide is needed.

SUMMARY

In one embodiment, a phytotoxic gas is injected into an enclosed space on a field to weaken and/or kill undesirable plants (also known as "weeds") growing from or on the soil surface prior to the use of the field for agricultural purposes. A phytotoxic gas is a gas that is poisonous to plants. Depending on the implementation, the above-described phytotoxic gas can be any gas containing ozone, or any gas containing sulfur dioxide, or any combination thereof or with other gases such as ammonia, nitric oxide, nitrogen dioxide, and hydrogen fluoride.

In one implementation, an impermeable or semi-permeable membrane is laid down on the soil surface to form the enclosed space (also called "treatment space") between the soil surface and the membrane. In one example, the edges of the membrane are covered with soil to at least partially (or even completely) seal the treatment space. In another example, the edges of the membrane are held against the soil surface by clips inserted into the soil to again partially or completely seal the treatment space. A phytotoxic gas, when injected into the treatment space, diffuses throughout the treatment space, contacts surfaces of any plants located therein, and weakens and/or kills one or more cells of such plants.

In one embodiment, a phytotoxic gas is injected into the treatment space through a gas injector located near the center of the treatment space. In such an embodiment, the phytotoxic gas may be supplied by a hand-held or shoulder mounted container (called "gas supplier"), although a vehicle mounted container

can also be used. In another embodiment, the phytotoxic gas is injected into the treatment space using a lattice arrangement of conduits to more uniformly deliver the phytotoxic gas into the treatment space.

Instead of being located near the center, the gas injector can be located at one end of an elongated treatment space with a vent being located at the other end. Specifically, in one embodiment, when a phytotoxic gas is injected into the treatment space, a source of low pressure is simultaneously provided to the treatment space (in a process called "venting") to ensure adequate passage of the phytotoxic gas into and out of the treatment space. In another embodiment, the soil is removed from the field and is brought into a chamber, and such soil is exposed to the phytotoxic gas.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGs. 1A-1C illustrate methods for treating undesirable plant growth from or on the soil surface by injecting a gas containing a phytotoxic gas into a treatment space formed between the soil surface and a membrane covering the soil surface in accordance to embodiments of the present invention.

FIGs. 2A-2C illustrate cross sectional views of a raised bed of the soil covered by the membrane to create the treatment space of FIGs. 1A-1C in accordance to three embodiments.

FIGs. 3A and 3B illustrate gas injectors of FIGs. 1A-1C.

FIG. 4 illustrates an arrangement of gas injectors to uniformly distribute the gas containing the phytotoxic gas into the treatment space of FIGs. 1A-1C.

FIGs. 5A and 5B illustrate, in block diagrams, methods for producing and injecting phytotoxic gas in to the treatment space of FIGs. 1A-1C.

FIGs. 6A and 6B illustrate, in block diagrams, methods for in-vitro treatment of plants growth from or on the soil surface using an enclosed chamber.

FIGs. 7A-7C illustrate the use of phytotoxic gas for controlling undesirable plant growth in conjunction with conventional agricultural processes to grow plants in accordance to two embodiments.

DETAILED DESCRIPTION

In one embodiment, a membrane 3 (FIG. 1A) is placed over a surface 2s of a soil 1 in a field 2 ("tarping"), and a space 4 enclosed therebetween is injected with a gas to weaken and/or kill plants 28 (FIGs. 2A and 2B) located in space 4. In one embodiment, a plant is considered weakened even if a single plant cell is killed by exposure to the injected gas. In another embodiment, a plant is considered weakened if a majority of the leaves show signs of degradation such as necrosis or yellowing a few days (e.g., less than 10 days) after treatment.

Tarping prevents the escape of the injected gas to the atmosphere, which may be harmful to the environment. Tarping also prolongs the exposure of plants 28 to the injected gas and conserves the use of the injected gas, which may be expensive to produce. Tarping further create a solarization effect that helps to weaken and/or kill plants 28. "Solarization" means exposure of tarped soil 1 to the sun to increase the temperature of space 4 and soil 1 from the green-house effect. Conventional tarping equipment is used to manually or automatically tarp field 2.

In one implementation, membrane 3 is a clear plastic membrane that is either impermeable or semi-permeable. Membrane 3 is, for example, a clear plastic polyethylene mulch. In one variation, the edges of membrane 3 are covered with soil 1 to create space 4 and to partially or completely seal the edges of membrane 3 to surface 2s (FIG. 2A). In another variation, the edges of membrane 3 are held against surface 2s by clips 24 (FIG. 2B) to create space 4 and to partially or completely seal the edges of membrane 3 to surface 2s.

Examples of the injected gas (also called "phytotoxic gases") are any gas that includes ozone, sulfur dioxide, ammonia, nitric oxide, nitrogen dioxide, or hydrogen fluoride at concentrations above the average levels (e.g., ambient levels) normally found in the atmosphere (e.g., three times the ambient levels). Ambient levels of ozone in the atmosphere range from 0.01 to 0.15 parts per million ("ppm") and ambient levels of sulfur dioxide range from 0.01 to 0.25 ppm. Plants 28 that are killed in the above-described manner include weeds, algae, fungus, and any other plants found in space 4. The tarping of surface 2s and the injection of

one or more phytotoxic gases into space 4 to weaken and/or kill plants 28 are collectively referred to as a "phytotoxic treatment."

Soil 1 is any natural or artificial substance used for rooting and plant growth purposes such as clay, sand, rock or other organic substrates. Soil 1 is suitable for agricultural or horticultural plant growth purposes and includes weeds growing on or from surface 2s. Soil 1 is prepared in any conventional manner suitable for subsequent agricultural purposes. Conventional processes such as shanking, discing, bed forming, bed pulling, and bed shaping are used to prepare soil 1 in field 2 for agricultural purposes. In one embodiment, soil 1 is free of phytotoxic gases above ambient levels prior to the injection of phytotoxic gas in space 4.

Field 2 is any space used for plant growth purposes such as open fallow, cultivated fields, seed beds, orchards, vineyards, and containerized soils such as pots of soil. Conventional processes such as shanking, discing, bed pulling, bed forming, and bed shaping are used to form raised beds in field 2 (FIG. 2A).

In one implementation, a gas supplier 7A (FIG. 1A) supplies a phytotoxic gas to space 4. Gas supplier 7A is coupled to a gas delivery line 16. In one variation, a slit is cut in membrane 3 and gas delivery line 16 is inserted into space 4. In another variation, gas delivery line 16 is coupled to a connector device 14 coupled to membrane 3. Connector 14 facilitates the passage of the injected gas from gas delivery line 16 to within space 4. Connector 14 is, for example, sealed to membrane 3 so that no gases escape from space 4 to the atmosphere through or around connector 14.

In one variation, connector 14 couples line 16 to a gas injector 5 (FIG. 3A) that injects the phytotoxic gas to space 4. Injector 5 is, for example, a short length of open-ended pipe or tubing attached to connector 14. In another variation, connector 14 couples line 16 to a gas injector 6 (FIG. 3B) that injects the phytotoxic gas to space 4. Injector 6 is, for example, an extended hollow pipe or tubing having one or more holes 17 that distributes the phytotoxic gas into space 4.

In one implementation, an arrangement of gas delivery lines 16 (FIG. 4) is disposed horizontally on or adjacent to membrane 3 over surface 2s of field 2. This

arrangement includes multiple injectors 5 with open ends inserted into space 4. Although variations of gas injectors and their arrangements are described above, any conventional gas injector and arrangement can be used. Furthermore, gas injectors and their arrangements can be either stationary or moveable, permanent or temporary.

After being injected, the phytotoxic gas disperses throughout space 4 and contacts the surfaces of plants 28. The phytotoxic gas then weakens and/or kills one or more cells of plants 28.

In one implementation, membrane 3 covers a raised bed 20 (FIG. 2A) whereby the edges of membrane 3 are covered with soil 1 to create space 4 and to seal the edges of membrane 3 to surface 2s. Raised bed 20 is, for example, 40 inches wide and 9 inches tall. In another variation, the edges of membrane 3 are held against surface 2s by clips 24 (FIG. 2B). Clips 24 are inserted through membrane 3 into soil 1, which frictionally retains clips 24. Although illustrated in a certain orientation, clips 24 may be inserted in other orientations to hold the edges of membrane 3 against surface 2s.

In one variation, gas delivery line 16 supplies one phytotoxic gas from gas supplier 7A to space 4. Line 16 is coupled to a valve 15 that controls the flow rate of the phytotoxic gas from gas supplier 7A. Connector device 14 couples valve 15 to one or more gas injectors, such as injector 5 or injector 6, within space 4. The above-described preparation of raised bed 20 can be repeated for the remaining raised beds in field 2. Please note that in other variations, line 16 supplies a gas containing more than one phytotoxic gases from gas supplier 7B or 7C (to be described later).

In one implementation, a connector 14A, a valve 15A, and an exhaust line 16A (FIGs. 2A and 2B) vent the injected phytotoxic gas from space 4 during the application of the phytotoxic gas or at the conclusion of the application of the phytotoxic gas. In one variation, the vented gases containing the phytotoxic gas are directed to an absorption/destruction chamber 128. Absorption/destruction chamber 128 is, for example, available from Hankin Atlas Ozone System, Ltd. of Toronto, Ontario. Absorption/destruction chamber 128 includes an absorption or

reactive agent that removes or destroys any unconsumed phytotoxic gas. The absorption or reactive agent in chamber 128 includes activated carbon, manganese dioxide, and any other catalyst or other agents capable of destroying the specific phytotoxic gas. In one variation using ozone as the phytotoxic gas (to be described later), the vented gases are heated to thermally destruct the ozone. The gases at outlet 129 of chamber 128 are environmentally safe and can be released to the atmosphere.

In one variation, connector 14A, valve 15A, exhaust line 16A, and chamber 128 is located at an opposing end of space 4 from the point of phytotoxic gas injection (see FIG. 1A-1C). This ensures that injected phytotoxic gas travels the length of space 4 before it is vented to the atmosphere. Other arrangement of connector 14A, valve 15A, exhaust line 16A, and chamber 128 is possible. For example, multiple points of venting may be used when multiple points of injection are used.

When first injected into space 4, the phytotoxic gas forces out the gases previously present in space 4 through connector 14A. After the phytotoxic gas is injected for a period of time, the later injected phytotoxic gas forces out the earlier injected phytotoxic gas through connector 14A. Thus, simultaneously injecting and venting the phytotoxic gas allow a more rapid dispersion of the phytotoxic gas through space 4 than simply injecting the phytotoxic gas and displacing the ambient gases from space 4 into soil 1.

In one implementation, gas supplier 7A is a gas container or a gas bottle. Gas supplier 7A is, for example, a lecture bottle from Fisher Scientific International of Hampton, New Hampshire (Catalogue No. 10-599W). Gas supplier 7A stores, for example, a gas containing sulfur dioxide with a pressure greater than 1.0 pounds per square inch gauge ("psig") and a sulfur dioxide concentration equal to or greater than 0.5 ppm of the gas. With pressure greater than 1.0 psig, the gas containing sulfur dioxide is able to force the other gases present in space 4 out of space 4 through soil 1 or through the previously described connector 14A, valve 15A, exhaust line 16A, and chamber 128. With sulfur dioxide concentration equal to or greater than 0.5 ppm, the gas has a sulfur dioxide

concentration that is more than the ambient levels normally found in the atmosphere. In general, the gas injected into space 4 has sulfur dioxide concentrations several times greater than ambient levels, e.g., 3 times or even 50 times depending on the ambient level.

In this implementation, the gas containing sulfur dioxide is injected into space 4 such that the multiplication of the sulfur dioxide concentration and exposure duration is greater than 1000 parts per million-minute ("ppm-min") within a 24 hour period (the result is known as "exposure dosage"). This exposure dosage causes a majority of plants 28 to suffer more than 50% leaf surface damage. Leaf surface damage include degradation such as necrosis and yellowing. The gas containing sulfur dioxide has, during and after the phytotoxic treatment, a time weighted average sulfur dioxide level in the air over field 2 that results in human exposure levels of less than each of the following two levels allowed by the U.S. Occupational Safety and Health Administration Department: (1) 2.0 ppm in eight hours and (2) 5.0 ppm in fifteen minutes.

In one experiment, gas supplier 7A supplied a sulfur dioxide gas to a 3 ft. × 3 ft. space 4 to weaken and/or kill grasses growing on surface 2s. In this experiment, space 4 is configured according FIG. 2A and 3B with the exception of venting with connector 14A, valve 15A, exhaust line 16A, and chamber 128. In this experiment, gas supplier 7A was a lecture bottle that supplied sulfur dioxide gas at a rate of 3.25 milliliter per minute ("mil/min") at 6.0 psig into the center of space 4. In this experiment, gas supplier 7A supplied the sulfur dioxide gas for an exposure duration such that the exposure dosage is 1,000 ppm-min within a 24-hour period. Membrane 3 was removed at the termination of the exposure duration to limit further exposure of the grasses to sulfur dioxide. A comparison of the lethal efficacy of the above phytotoxic treatment with the lethal efficacy in absence of any phytotoxic treatment is presented in Table 1.

TABLE 1

Phytotoxic Gas	Exposure Duration (min)	Exposure Dosage (ppm-min)	% of Plants with Greater than 50 % of Leaf Surface Damage in Grasses	% Mortality in Grasses
Untreated	0	0	0	5
SO_2	10	1,000	58	20

Initial evaluation of leaf surface damage was made 2 days after the treatment. "% of Plants with Greater than 50% of Leaf Surface Damage in Grasses" is the number of plants in space 4 in which greater than 50% of the leafs on the plant show signs of degradation including necrosis and yellowing at 2 days after the phytotoxic treatment divided by the initial number of plants in space 4. Evaluation of the treated and untreated plant mortality was made 10 days after the phytotoxic treatment. "% Mortality in Grasses" is the number of dead plants in space 4 at 10 days after the phytotoxic treatment divided by the initial number of plants in space 4. As Table 1 shows, when plants 28 are exposed to a sulfur dioxide gas such that exposure dosage is greater than or equal to 1,000 ppm-min, a majority of the plants have greater than 50% leaf damage. Please note that 5% of grasses died from natural causes even without phytotoxic treatment.

The levels of sulfur dioxide in the air from the experiment reported in Table 2 were measured and found to be below the human exposure thresholds of (1) 2.0 ppm in eight hours and (2) 5.0 ppm in fifteen minutes allowed by the U.S. Occupational Safety and Health Administration Department. Thus, the use of sulfur dioxide is safe for in-situ and in-vitro applications in accordance to the exposure levels set by the U.S. Occupational Safety and Health Administration Department.

In one implementation, a gas supplier 7B (FIG. 1B) injects one or more phytotoxic gases to space 4. Gas supplier 7C includes a gas container 18A, a gas container 18B, and a mixing chamber 21. Each of gas containers 18A and 18B contains a phytotoxic gas that can be mixed in chamber 21 to various proportions.

Chamber 21 is coupled to the previously described gas delivery line 16 to deliver the a gas containing one or more phytotoxic gases to space 4 according to the methods described above.

In one variation, a self-propelled field device 13, such as a tractor, moves a skid or trailer mounted gas supplier 7B in field 2. Self propelled field device 13 can be replaced by any conventional vehicle or equipment used to move gas supplier 7B. In another variation, gas supplier 7B is incorporated into a vehicle rather than being skid or trailer mounted.

In one implementation, a gas supplier 7C (FIG. 1C) supplies a gas containing ozone to space 4. The gas further includes a carrier gas such as air, oxygen, or other gas that contains oxygen. Gas supplier 7C is any device used to supply a gas containing ozone. In one variation, gas supplier 7C is a Pacific Technologies Model G24 from Pacific Technologies of Brentwood, California. Gas supplier 7C includes an electric generator 8, an ozone generator with power supply 9, an air compressor 10, and an air purification system 11. Gas supplier 7C also includes an ozone chamber 12, such as 10 cubic feet, to equalize pressure imbalances or mix or dilute the ozone containing gas with other gaseous elements, such as other phytotoxic gases.

In one variation, a gas containing ozone is injected into space 4 without mixing with any other phytotoxic gases (e.g., sulfur dioxide, ammonia, nitric oxide, nitrogen dioxide, or hydrogen fluoride). In another variation, prior to injection, chamber 12 mixes a gas containing ozone with one or more other phytotoxic gases (e.g., sulfur dioxide, ammonia, nitric oxide, nitrogen dioxide, or hydrogen fluoride).

In one variation, self-propelled field device 13 moves a skid or trailer mounted gas supplier 7C. Self propelled field device 13 can be replaced by any conventional vehicle or equipment used to move gas supplier 7C. In another variation, gas supplier 7C is incorporated into a vehicle rather than being skid or trailer mounted.

When injected into space 4, the gas containing ozone comes into contact with the surfaces of plants 28 and the ozone oxidizes their cell walls to weaken

and/or kill plants 28. Space 4 is free of obstacles that inhibit free flow of the gas containing ozone so that the ozone reaches all of plants 28 within space 4 and attacks the cell walls of plants 28.

After sufficient exposure (shown later in Table 2) of an undesirable plant to the ozone within space 4, the cell walls of the undesirable plant begin to lyse and release the cytoplasm of the cells, thereby causing death to the cells and/or the undesirable plant that includes the cells. If the number of cells that is killed by exposure to ozone is less than that required to kill the undesirable plant, the undesirable plant is weakened by the partial destruction of its cell membranes. The weakened undesirable plant is susceptible to other natural or artificial biocidal agents and processes, such as solarization, and eventually dies before a natural death. Even if the undesirable plant is not killed by ozone exposure, the weakened undesirable plant has a reduced detrimental effect on subsequent agricultural plant growth compared to an unexposed undesirable plant.

In one implementation, gas supplier 7C generates a gas containing ozone that has a pressure greater than 1.0 psig and an ozone concentration equal to or greater than 0.5 ppm of the gas. With pressure greater than 1.0 psig, the gas containing ozone is able to force the other gases present in space 4 prior to injecting the gas containing ozone out of space 4 through soil 1 or the previously described connector 14A, valve 15A, exhaust line 16A, and chamber 128. With ozone concentration equal to or greater than 0.5 ppm, the gas has an ozone concentration that is more than the ambient levels normally found in the atmosphere. In general, the gas injected into space 4 has ozone concentrations several times greater than ambient levels, e.g., 3 times or even 50 times depending on the ambient level.

In this implementation, the gas containing ozone is injected into space 4 in a concentration and an exposure duration that produces an exposure dosage (e.g., greater than 250 ppm-min within a 24 hour period) that causes a majority of plants 28 to suffer more than 50% leaf surface damage. The gas containing ozone has, during and after ozone treatment, a time weighted average ozone level in the air over field 2 that results in human exposure levels of less than each of the following

two levels allowed by the U.S. Occupational Safety and Health Administration Department: (1) 0.1 ppm in eight hours and (2) 0.3 ppm in fifteen minutes.

In one experiment, gas supplier 7C injects a gas containing ozone into 3 ft. × 3 ft. spaces 4 to weaken and/or kill grasses growing on surfaces 2s. In this experiment, spaces 4 are configured according FIG. 2A and 3B with the exception of venting with connector 14A, valve 15A, exhaust line 16A, and chamber 128. In this experiment, spaces 4 are exposed to the gas containing ozone for an exposure dosage of 250, 1000, and 5000 ppm-minutes within a 24 hour period. In another experiment, a space 4 is exposed to a gas containing ozone and sulfur dioxide for an exposure dosage of 1000 ppm-min within a 24 hour period.

Membrane 3 was removed at the termination of each of the exposure duration to limit further exposure of the grasses to the gases containing ozone or sulfur dioxide, or the gas containing ozone mixed with sulfur oxide. A comparison of the lethal efficacy of the above phytotoxic treatment with the lethal efficacy in absence of any phytotoxic treatment is presented in Table 2. The previously results from Table 1 are also carried over into Table 2.

TABLE 2

Phytotoxic Gas	Exposure Duration (min)	Exposure Dosage (ppm-min)	% of Plants with Greater than 50 % of Leaf Surface Damage in Grasses	% Mortality in Grasses
Untreated	0	0	0	5
O_3	2.5	250	57	41
O_3	10	1,000	91	77
O_3	50	5,000	99	100
$O_3 + SO_2$	10 (both)	1,000 (both)	89	94

SO_2	10	1,000	58	20

In this experiment, a corona discharge ozone generator produced ozone at 1% (weight to weight) ozone in air diluted with air to 0.01% (100 ppm) and injected at 15 cubic feet per hours (cfh) at 5.0 psig into the center of 3 ft. × 3 ft. space 4, e.g., raised beds covered with plastic. A lecture bottle provided sulfur dioxide at a rate of 3.25 ml/min at 6.0 psig. The sulfur dioxide is injected into space 4 directly at the outlet of the ozone/air injector.

Initial evaluation of leaf surface damage was made 2 days after the phytotoxic treatment. Evaluation of the treated and untreated plant mortality was made 10 days after phytotoxic treatment. As Table 2 illustrates, a majority of the plants have greater than 50% leaf damage when exposed to a gas containing ozone such that the exposure dosage is greater than or equal to 250 ppm-min.

The levels of ozone in the air from the experiments reported in Table 2 were measured and found to be below the human exposure thresholds of (1) 0.1 ppm in eight hours and (2) 0.3 ppm in fifteen minutes allowed by the U.S. Occupational Safety and Health Administration Department. The levels of sulfur dioxide in the air from the experiment reported in Table 2 were measured and found to be below the human exposure thresholds of (1) 2.0 ppm in eight hours and (2) 5.0 ppm in fifteen minutes allowed by the U.S. Occupational Safety and Health Administration Department. Thus, the use of ozone and sulfur dioxide are safe for in-situ and in-vitro applications in accordance to the exposure levels set by the U.S. Occupational Safety and Health Administration Department.

As seen from Table 1 and Table 2, injection of sufficiently phytotoxic gas at a low pressure (e.g., 6 psig) into space 4 and exposure of the plants to the phytotoxic gas for a minimum period of time (dependent on the concentration of the phytotoxic gas) reduces the survival of plants 28.

In one embodiment, a gas generator 22 (FIG. 5A) produces a phytotoxic gas in-situ at field 2. Generator 22 is coupled to a valve 120, such as a standard 316 stainless steel valve, that controls the amount of phytotoxic gas provided via gas delivery line 16 to injector 5 or 6 through connector 14. Gas delivery line 16 can

be a rigid conduit, such as standard 1" 316 stainless steel piping, or a flexible conduit, such as standard 5/8" PVC hose.

A gas concentration measuring device 122A is optionally provided in space 4 at a point away from a point of injection of the phytotoxic gas to determine the actual concentration of phytotoxic gas in space 4. In the embodiments described in reference to FIGs. 3A, 3B, and 4, gas concentration measuring device 122A is optionally placed between 1 foot and the furthest possible distance in space 4 from a point of gas injection. Gas concentration measuring device 122B is optionally provided to determine if any phytotoxic gas is emitted into the atmosphere. Concentration measurements from measuring device 122A or 122B can be used to estimate the end point of the phytotoxic treatment for achieving the desired results.

In one implementation, generator 22 produces sulfur dioxide gas. In another implementation, generator 22 produces a gas containing ozone from air or highly concentrated oxygen (see FIG. 5B). In one variation, generator 22 includes a chamber 115 (FIG. 5B) that produces a gas containing dried oxygen (a gas that includes oxygen from which moisture has been removed) by a conventional process such as air compression followed by refrigeration, pressure swing absorption with silica desiccant, molecular sieve, or membrane separation. Chamber 115 supplies the dried oxygen containing gas via a conduit to a filter 116. Filter 116 is, for example, a particulate or hydrocarbon filter. In this variation, gas concentration measuring devices 122A and 122B are, for example, High Concentration Meters produced by Anseros of Turbingen, Germany.

One or more valves 117 control the pressure of the dried purified oxygen containing gas supplied to an ozone generator 118 to optimize ozone output and limit over pressurization. Over pressurization can damage components such as electrodes of ozone generator 118 and occurs, for example, when the oxygen containing gas entering ozone generator 118 exceeds 25 psig. Valve 117 is a conventional pressure-regulating valve.

Ozone generator 118 includes an ultraviolet ozone generator, a conventional corona ozone generator, or any one of different but well-known variants thereof. Typically, ozone generator 118 can produce a concentration of

ozone by weight of up to 2% from air and up to 4% to 10% from highly concentrated oxygen (90% to 98%). A conventional pressure indicator device 119 is generally provided to monitor the pressure at which oxygen and other gases are introduced into ozone generator 118 and subsequently into gas delivery line 16. Ozone generator 118 is coupled to the previously described valve 120.

In one embodiment, surface 2s of soil 1 are phytotoxic treated in-vitro in a chamber 126 (FIG. 6A) used as space 4. In-vitro phytotoxic treatment of soil 1 may be necessary in greenhouse applications or for reducing damaging effects on other biological organisms in the field. In this embodiment, a container 26 of soil 1 suitable for subsequent agricultural or horticultural plant growth purposes and containing plants 28 growing on or from the surface 2s of soil 1 are transported to a chamber 126.

Generator 22 supplies a phytotoxic gas to an inlet 127 (FIG. 6A) of a phytotoxic chamber 126. Chamber 126 includes gas concentration measuring device 122A to determine the actual concentration of atmospheric pollutant in chamber 126. Chamber 126 is an enclosure which holds containers of soil 1 and into which the phytotoxic gas is injected. Chamber 126 can be any size room or chamber with the phytotoxic gas going in at one end and out at the other end.

The gases vented from chamber 126 are directed through a conduit to the previously described absorption/destruction chamber 128. The vented gases at outlet 129 of absorption/destruction chamber 128 are environmentally safe and can be released to the atmosphere.

In one implementation, generator 22 generates sulfur dioxide. In another implementation, generator 22 generates ozone and includes the previously described chamber 115, filter 116, valve 117, pressure gauge 119, and ozone generator 118 (see FIG. 6B).

The method for phytotoxic treatment of soil suitable for plant growth purposes can be used in conjunction with other agricultural methods such as irrigation, fertilization, and tilling. In one embodiment, soil 1 is tilled in action 801 (FIG. 7A). Soil 1 can be top soil of field 2 that was previously cultivated. Alternatively, soil 1 in action 801 is a soil used for other purposes and yet suitable

for plant growth purposes. Action 801 is followed by action 802. In action 802, soil 1 is formed into beds and shaped for the particular crop to be grown. Action 802 is followed by action 803.

In action 803, soil 1 is covered with membrane 3 and the edges of membrane 3 are sealed in soil 1, thereby creating a space 4. Action 803 is followed by action 804. In action 804, space 4 is injected with one or more phytotoxic gases as described above. The injection of one or more phytotoxic gases weakens and/or kills plants 28 growing from or on surface 2s of soil 1. In one implementation, membrane 3 is removed after the injection of one or more phytotoxic gases. In another implementation, membrane 3 is left on field 2. Action 804 is followed by optional action 805. In optional action 805, soil 1 is optionally fertilized with fertilizers such as calcium nitrate. Optional action 805 is followed by action 806.

In action 806, seeds are sown or seedlings are transplanted in soil 1. As previously described in one implementation, membrane 3 may be left on field 2 after the injection of one or more phytotoxic gases. In that implementation, seeds are sown or seedlings are transplanted through openings 30 (FIG. 2C) in membrane 3 and plants 32 from the seeds or seedlings grow through openings 30. Plants 32 (FIG. 2C) from seeds or seedlings experience enhanced growth due to absence of plants that were killed in action 804. Action 806 is followed by optional action 807. In optional action 807, soil 1 is optionally irrigated. Optional action 807 is followed by optional action 808. In optional action 808, pesticides are optionally sprayed or applied over the plants or soil. Optional action 808 is followed by action 809. In action 809, the crop is harvested.

In one implementation, the above actions are repeated for another season by starting at action 801 after completion of action 809. In another implementation, injectors 6 (FIG. 4) are used for fertilization in action 805, irrigation in action 807, and pesticide application in action 808.

In one embodiment, actions 801-809 occur in a different order such that action 805-808 occur in any sequence after actions 801-804 and prior to action 809. In this embodiment, optional action 805 can also occur prior to actions 801. For example, the actions can occur in the following sequence: 805, 801-804, 808, 806,

807, and 809 (FIG. 7B). Please note other sequences which can be used to with above the phytotoxic treatment.

In one embodiment, the actions occur in the following sequence: 801, 802, 806, 803, 804, 805, 807, 808, and 809 (FIG. 7C). In this embodiment, seeds are planted beneath soil 1 in action 806 and the phytotoxic treatment in actions 803 and 804 weakens and/or kills the plants growing on or from surface 2s but not the seeds beneath soil 1.

Phytotoxic treatment of plants growing on or from surfaces 2s as described above easily and efficiently kills the plants in an environmentally benign manner and provides a needed alternative to methyl bromide. The creation of space 4 for killing plants with phytotoxic gases also results in a low release of pollutants within the allowable human exposure levels.

Numerous modifications and adaptations of the embodiments described herein will be apparent to the skilled artisan in view of the disclosure. For example, the actions in FIG. 7A and 7B can occur in the following sequence: 801-804, 807, 806, 808, 805, and 809. Numerous such changes and modifications are encompassed by the attached claims.

CLAIMS

What is claimed is:

1. A method for controlling plant growth in a field, said method comprising:

covering a portion of said field with a membrane thereby creating an enclosed space between a surface of said field and said membrane; and

injecting a gas into said treatment space.

2. The method of Claim 1, wherein a plant has at least a portion in said space, said gas killing or weakening at least one cell of said portion of said plant.

3. The method of Claim 1, wherein said gas is a phytotoxic gas.

4. The method of Claim 3, wherein said gas includes one or more of ozone, sulfur dioxide, ammonia, nitric oxide, nitrogen dioxide, and hydrogen fluoride.

5. The method of Claim 4, wherein the soil of said field is free of said gas with concentration above an ambient level in said soil prior to said injecting.

6. The method of Claim 4, wherein said gas has a concentration in said enclosed space that is greater than several times said ambient level in the atmosphere.

7. The method of Claim 1, wherein said membrane is impermeable or semi-impermeable.

8. The method of Claim 1, further comprising generating said gas.

9. The method of Claim 1, further comprising mixing two or more compounds in gaseous form to generate said gas.

10. The method of Claim 1, further comprising at least partially sealing said membrane over said field.

11. The method of Claim 10, wherein said partially sealing comprises covering at least a portion of an edge of said membrane with said soil from said field.

12. The method of Claim 10, wherein said partially sealing comprises inserting a clip into said soil through at least a portion of an edge of said membrane, said clip holding said portion against said surface of said soil.

13. The method of Claim 1, further comprising venting from said space.

14. The method of Claim 13, wherein said venting comprises releasing another gas from said space, said another gas being present in said space prior to said injecting.

15. The method of Claim 13, wherein said venting comprises releasing said gas from said space.

16. The method of Claim 1, wherein said injecting comprises releasing said gas in at least one location within said space.

17. The method of Claim 1, wherein said injecting comprises releasing a gas comprising ozone such that plants within said space are subjected to exposure dosage that causes at least one of said plants to have leaf damage over a majority of a leaf surface.

18. The method of Claim 1, wherein said injecting comprises releasing a gas comprising ozone in a concentration for a time period such that the exposure dosage is equal to or greater than 250 parts per million-minutes within a 24 hour period.

19. The method of Claim 1, wherein said injecting comprises releasing a gas comprising ozone in a concentration for a time period such that a time weighted average ozone level in the air over said field results in an exposure to individuals of less than at least one level allowed the U.S. Occupational Safety and Health Administration Department.

20. The method of Claim 19, wherein said level is either of (a) 0.1 part per million in eight hours and (b) 0.3 part per million in fifteen minutes.

21. The method of Claim 1, wherein said injecting comprises releasing a gas comprising ozone such that the ozone has a concentration equal to or greater than 0.5 parts per million by weight of said gas.

22. The method of Claim 1, wherein said injecting comprises releasing a gas comprising sulfur dioxide such that plants within said space are subjected to exposure dosage that causes at least one of said plants to have leaf damage over a majority of a leaf surface.

23. The method of Claim 1, wherein said injecting comprises releasing a gas comprising sulfur dioxide in a concentration for a time period such that the exposure dosage is equal to or greater than 1000 parts per million-minutes within a 24 hour period.

24. The method of Claim 1, wherein said injecting comprises releasing a gas comprising sulfur dioxide in a concentration for a time period such that a time weighted average ozone level in the air over said field results in an exposure to individuals of less than levels allowed by the U.S. Occupational Safety and Health Administration Department.

25. The method of Claim 24, wherein said levels include (a) 2.0 part per million in eight hours and (b) 5.0 part per million in fifteen minutes.

26. The method of Claim 1, wherein said injecting comprises releasing a gas comprising sulfur dioxide such that the sulfur dioxide has a concentration equal to or greater than 0.5 parts per million by weight of said gas.

27. A method for controlling plant growth in a field, said method comprising:

forming and shaping beds on a surface of said field;

covering a portion of said field with a membrane thereby creating an enclosed space between said surface and said membrane; and

injecting a gas into said treatment space.

28. The method of Claim 27, wherein said bed has a height of 9 inches and a width of 40 inches.

29. The method of Claim 27, further comprising seeding or planting in said soil.

30. The method of Claim 29, further comprising reaping a harvest of plants.

31. The method of Claim 30, further comprising tilling said soil.

32. The method of Claim 31, further comprising irrigating said soil.

33. The method of Claim 32, further comprising applying a pesticide on said soil or plants growing on said soil.

34. The method of Claim 33, further comprising fertilizing said soil.

35. The method of Claim 34, further comprising repeating one of the previous actions

36. The method of Claim 34, wherein the actions occur in the following sequence: said tilling, said bed forming and shaping, said covering, said injecting, said fertilizing, said seeding or planting, said irrigating, said applying, and said reaping.

37. The method of Claim 34, wherein the actions occur in the following sequence: said fertilizing, said tilling, said bed forming and shaping, said covering, said injecting, said applying, said seeding or planting, said irrigating, and said reaping.

38. The method of Claim 34, wherein the actions occur in the following sequence: said tilling, said bed forming and shaping, said seeding or planting, said covering, said injecting, said fertilizing, said irrigating, said applying, and said reaping.

39. The method of Claim 34, further comprising removing said membrane subsequent to said injecting.

40. A system for controlling plant growth in a field, said system comprising:

a gas source;

a gas line coupled to said gas source;

a gas injector coupled to said gas line; and

a membrane placed over a portion of a soil surface in said field, at least a portion of said gas injector being located within a space between said membrane and said soil surface.

41. The system of Claim 40, wherein said gas injector is an open-ended pipe or tubing.

42. The system of Claim 40, wherein said gas injector is a pipe or tubing having one or more holes.

43. The system of Claim 40, wherein said gas line is disposed horizontally on or adjacent to said membrane.

44. The system of Claim 40, further comprising a valve coupled to said gas line and said gas injector.

45. The system of Claim 40, further comprising a connector located on said membrane, said connector coupled to said gas line and said gas injector.

46. The system of Claim 40, further comprising a clip inserted into said soil surface through at least a portion of an edge of said membrane.

47. The system of Claim 40, wherein said gas source is a container storing a gas.

48. The system of Claim 40, wherein said gas source is a gas generator.

49. The system of Claim 48, wherein said gas generator is an ozone generator.

50. The system of Claim 49, wherein said ozone generator is an ultraviolet ozone generator or a corona ozone generator.

51. The system of Claim 40, further comprising:

a connector located on said membrane; and

an absorption/destruction chamber coupled to said connector.

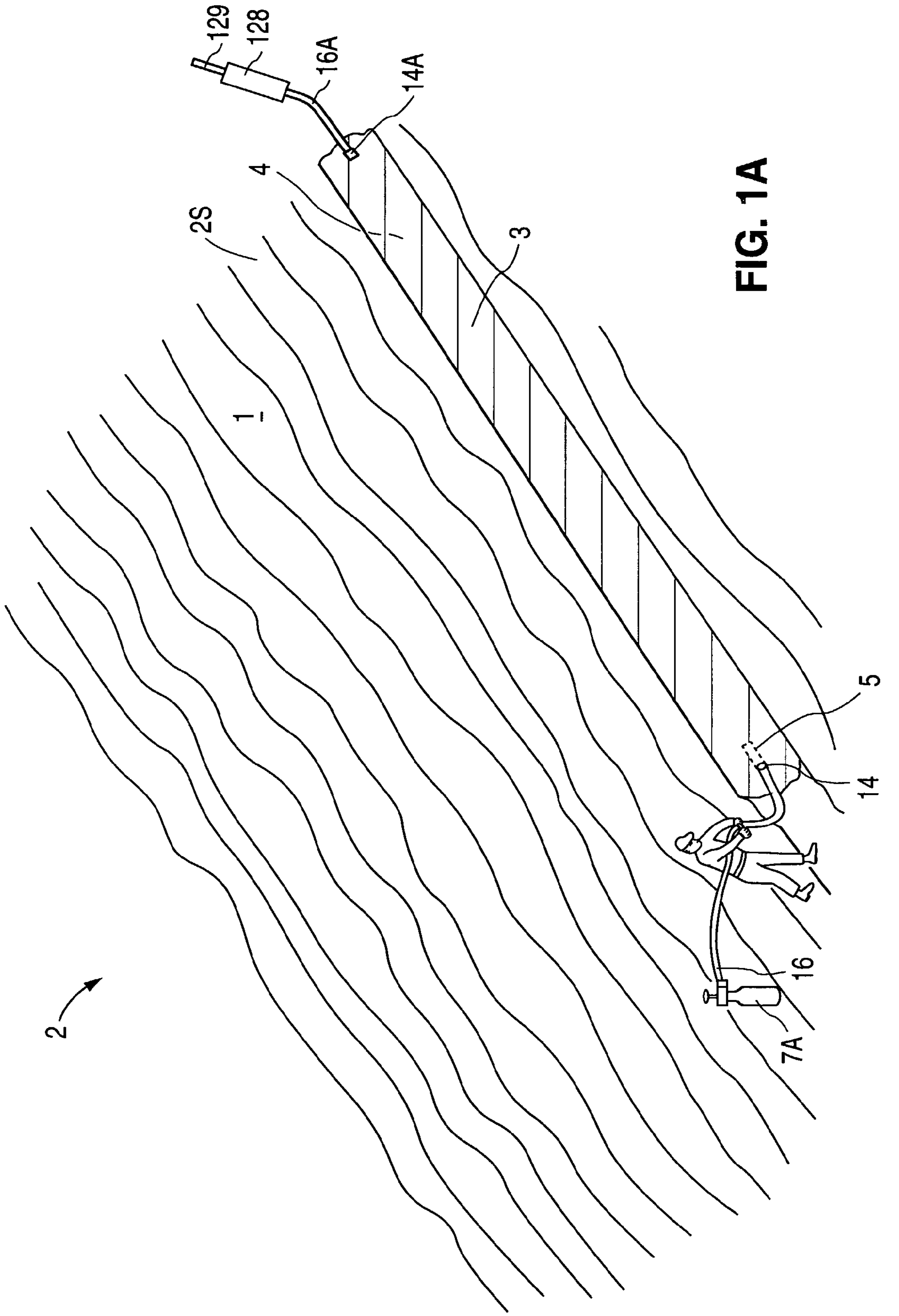

FIG. 1A

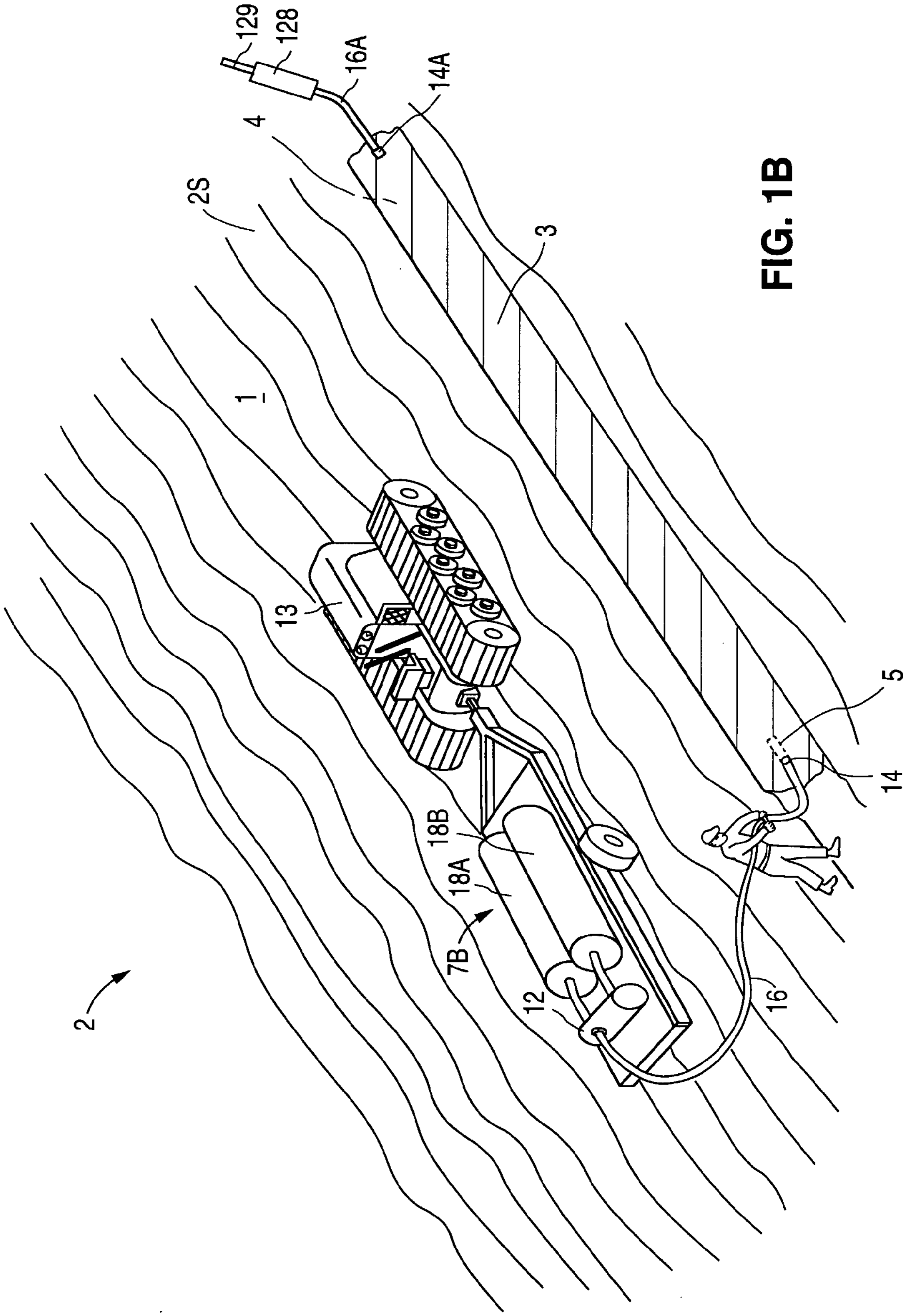

FIG. 1B

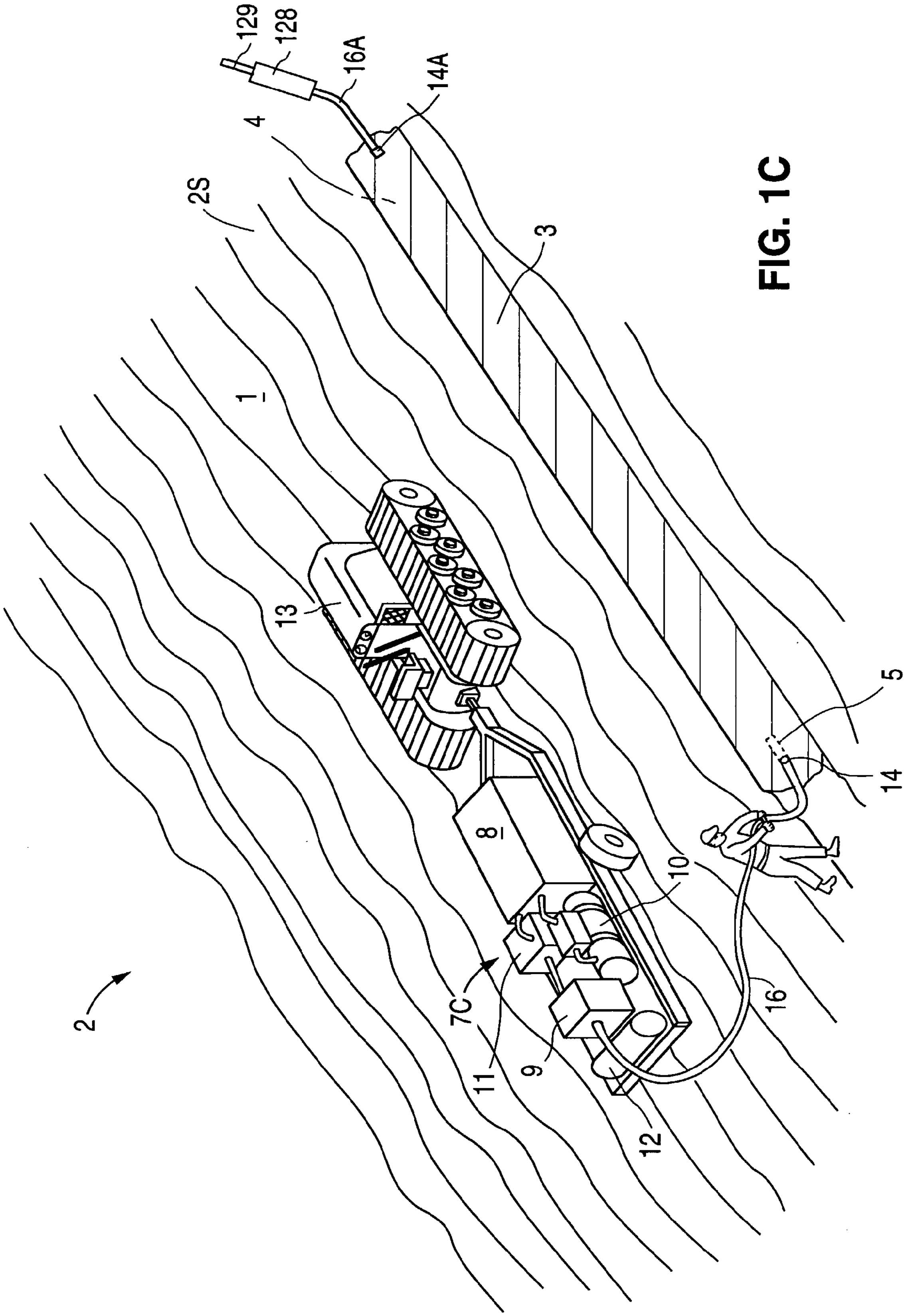

FIG. 1C

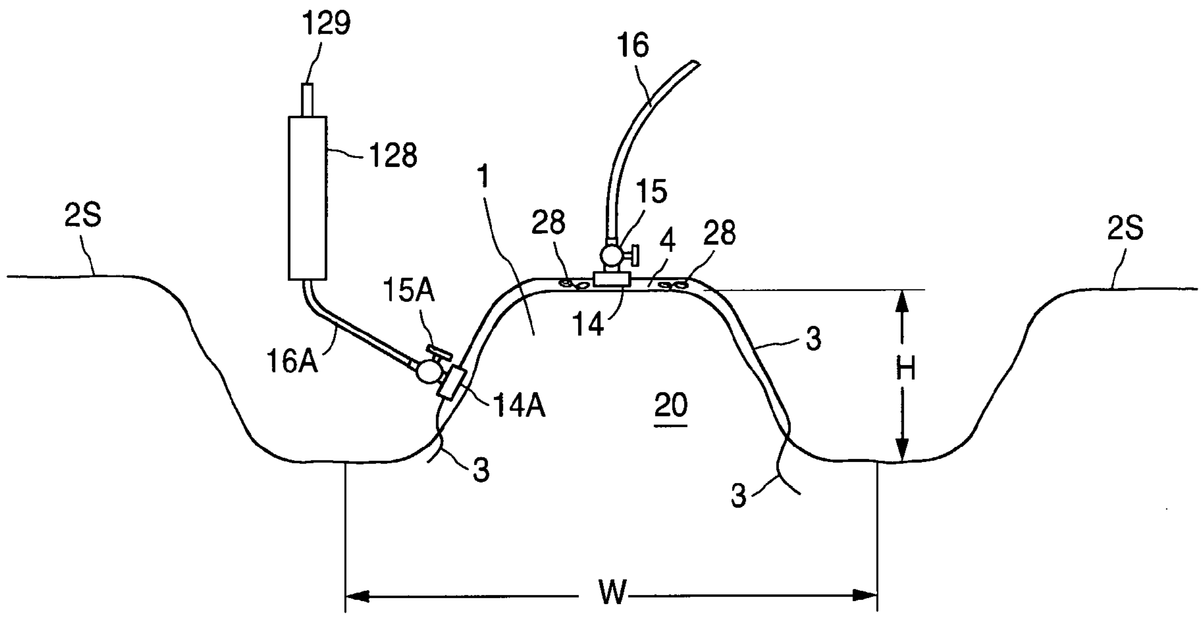
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FIG. 2A

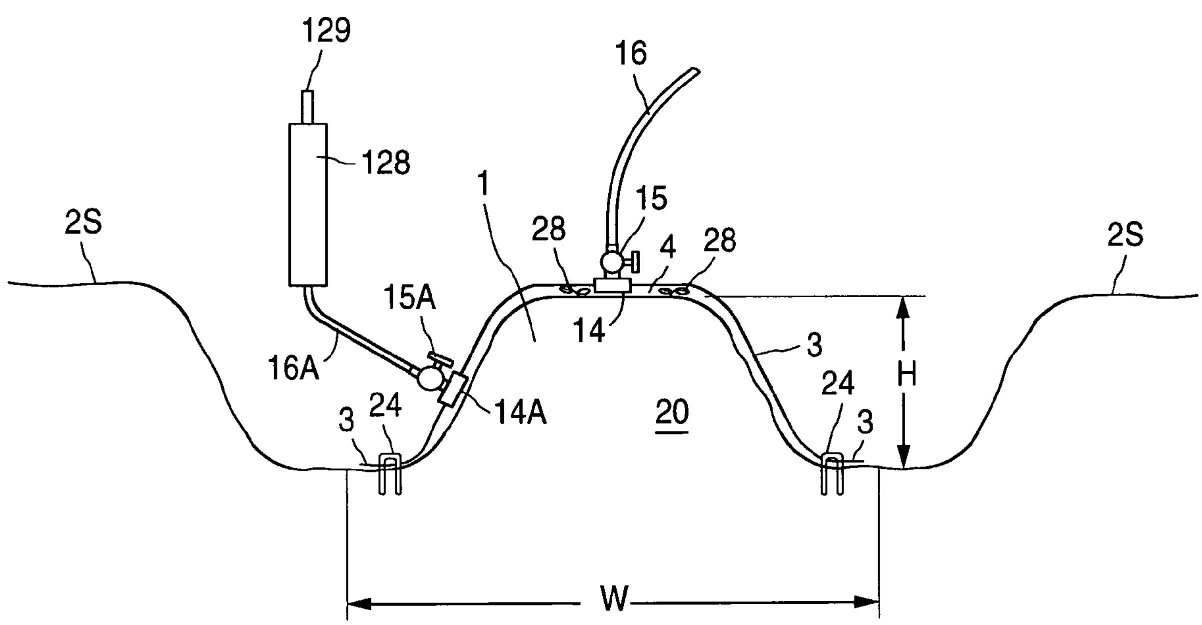
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FIG. 2B

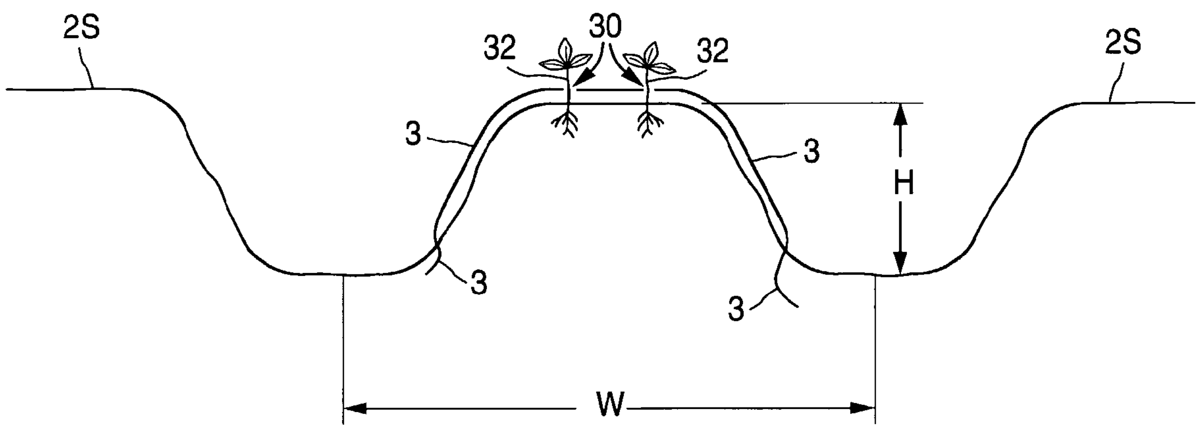


FIG. 2C

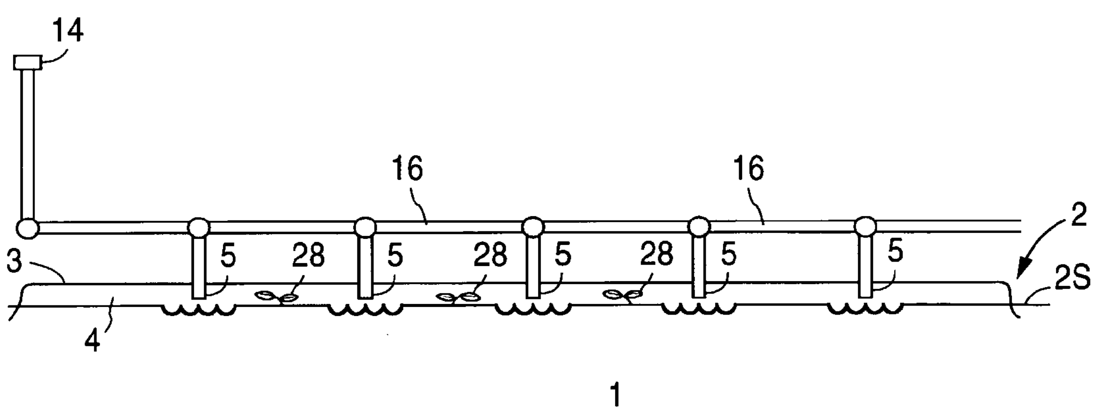


FIG. 4

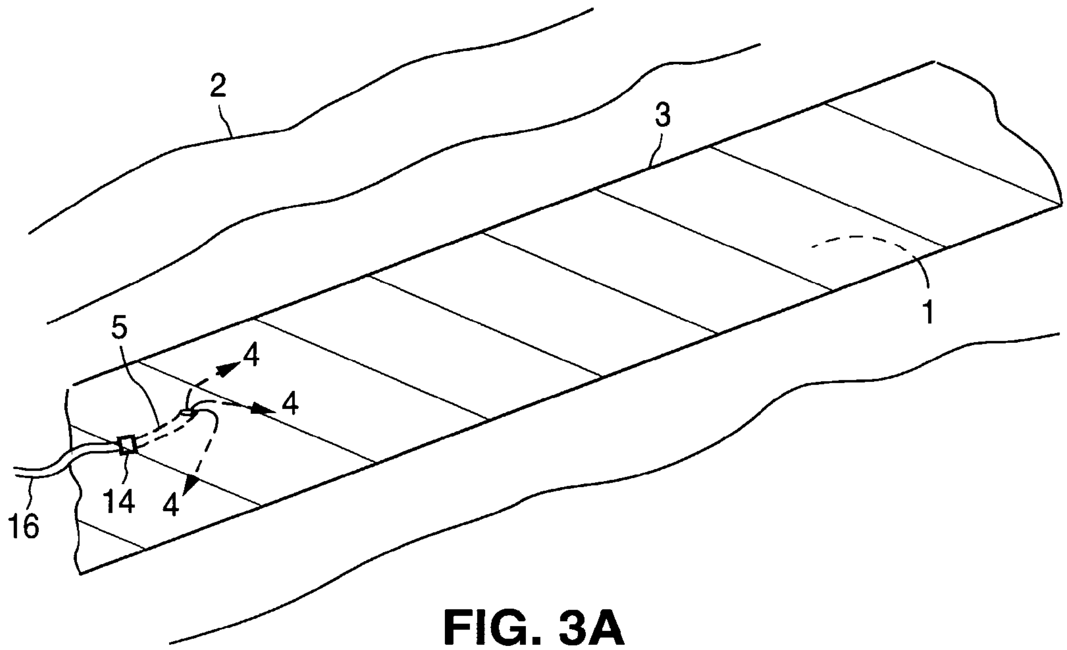


FIG. 3A

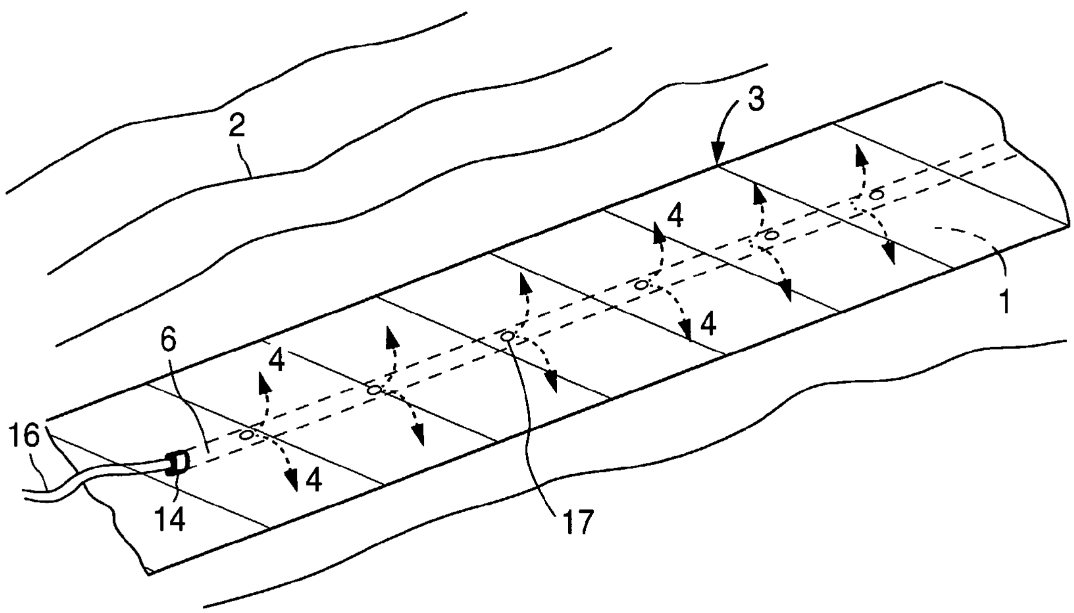


FIG. 3B

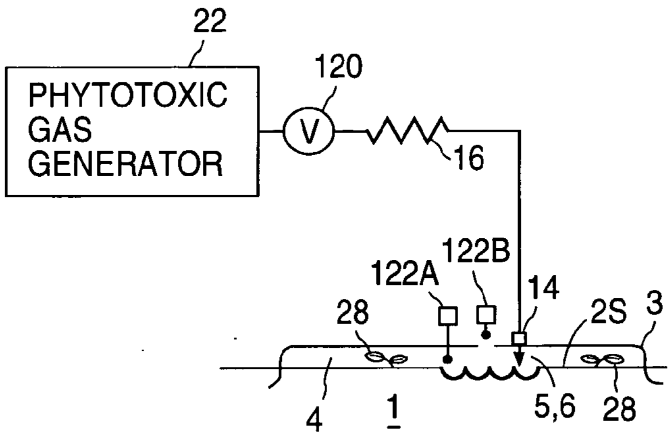


FIG. 5A

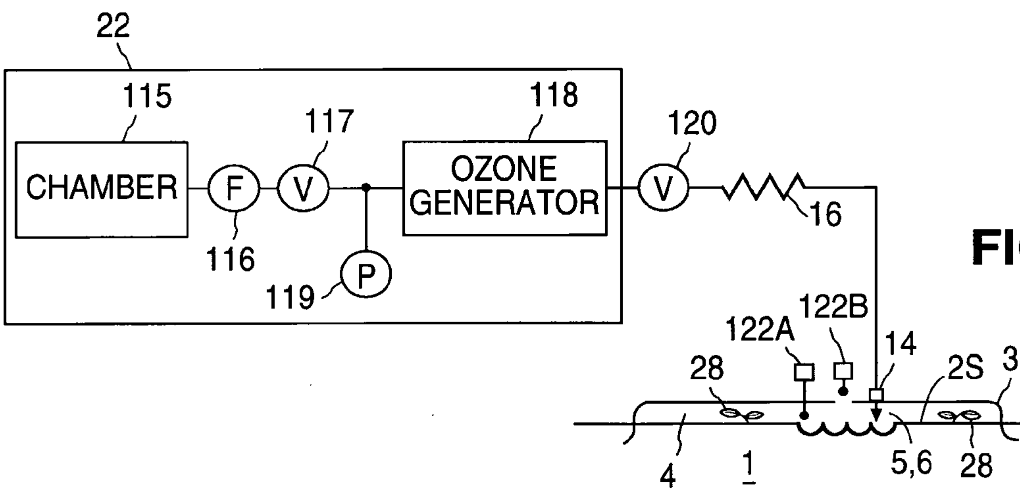


FIG. 5B

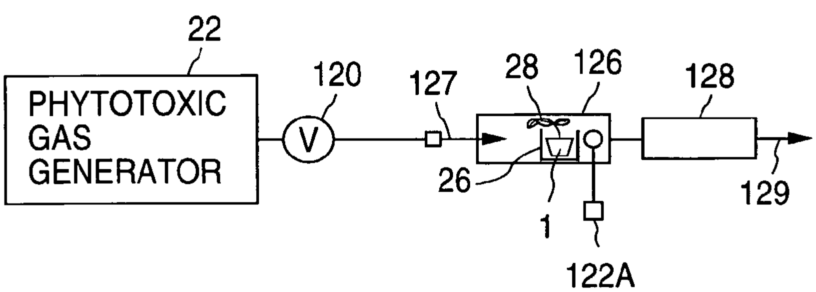


FIG. 6A

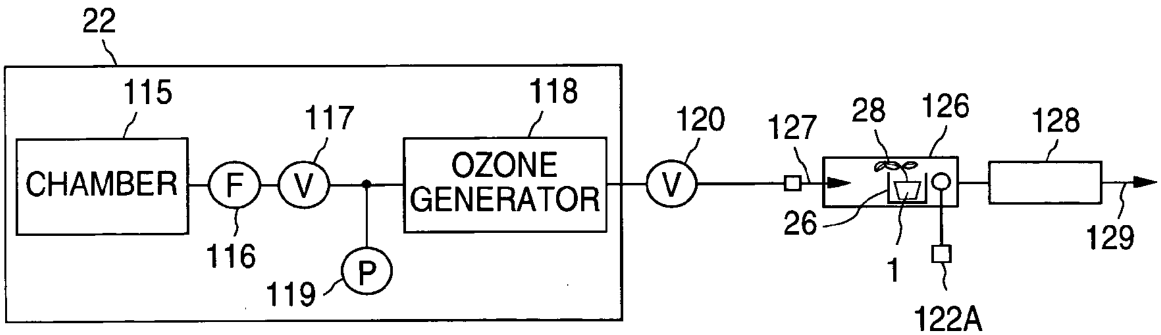
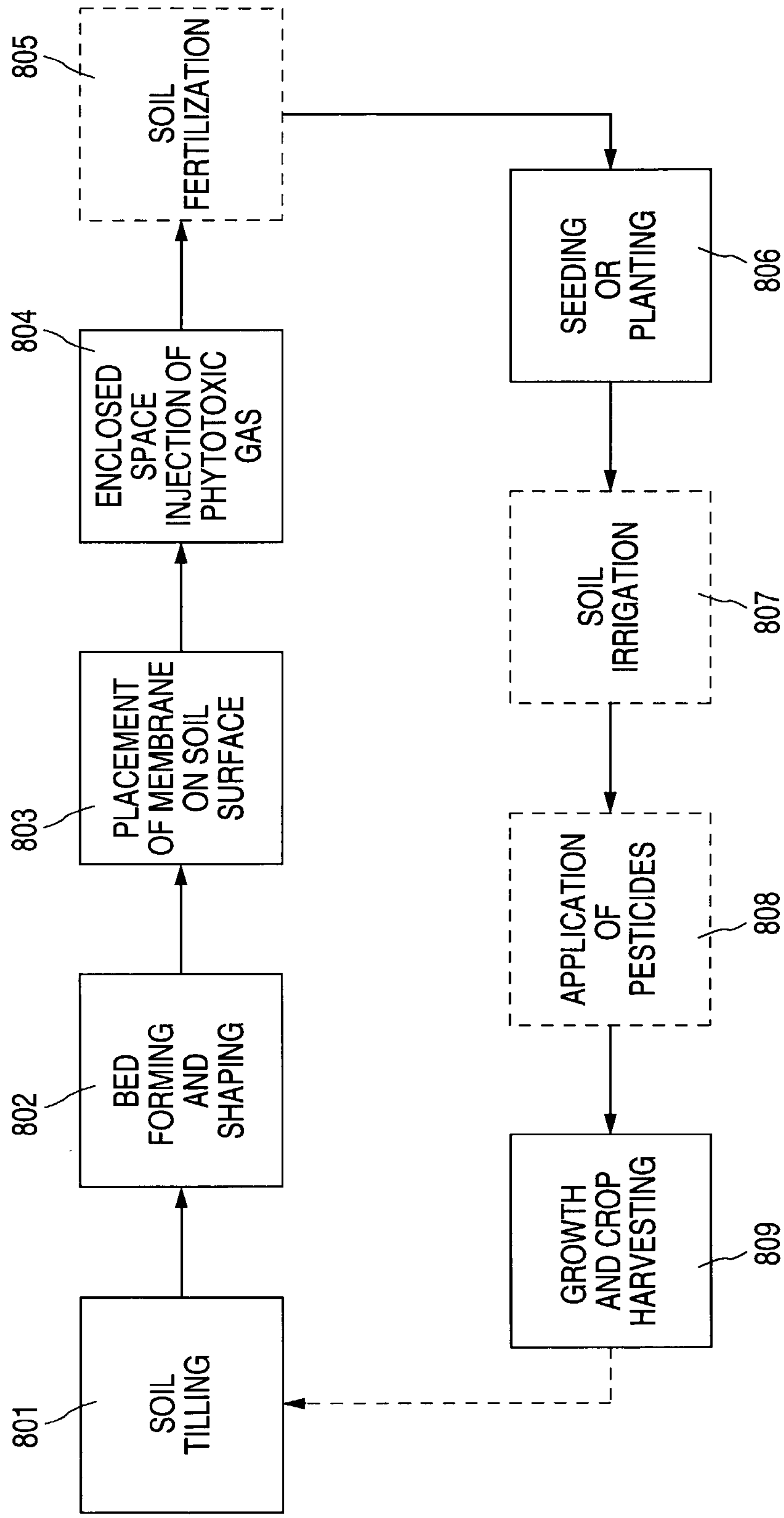


FIG. 6B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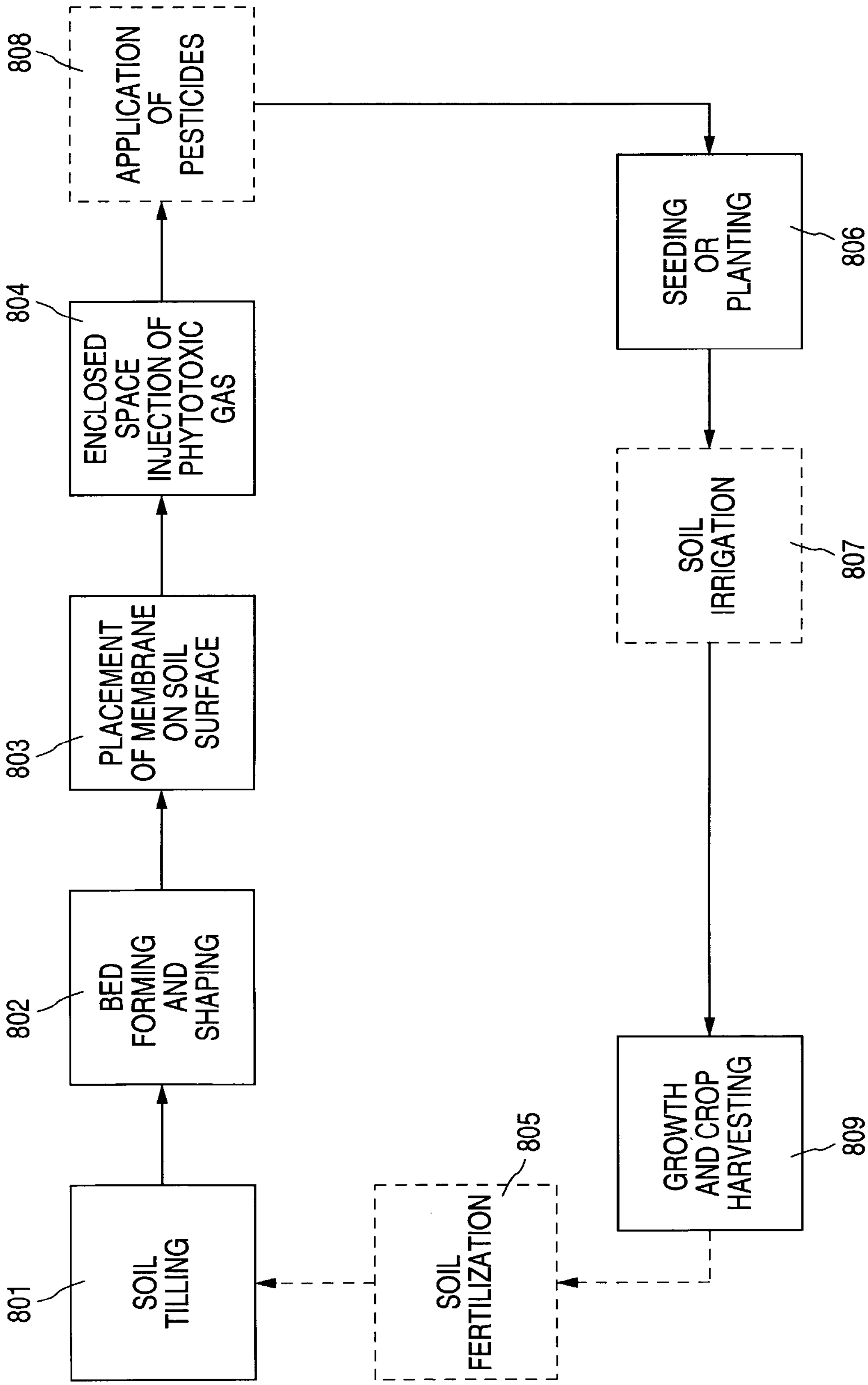
SOIL TILLING
802
BED FORMING AND SHAPING
803
PLACEMENT OF MEMBRANE ON SOIL SURFACE
804
ENCLOSED SPACE INJECTION OF PHYTOTOXIC GAS
805
SOIL FERTILIZATION
806
SEEDING OR PLANTING
807
SOIL IRRIGATION
808
APPLICATION OF PESTICIDES
809
GROWTH AND CROP HARVESTING

FIG. 7A



SOIL TILLING
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BED FORMING AND SHAPING
802
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ENCLOSED SPACE INJECTION OF PHYTOTOXIC GAS
804
APPLICATION OF PESTICIDES
808
SEEDING OR PLANTING
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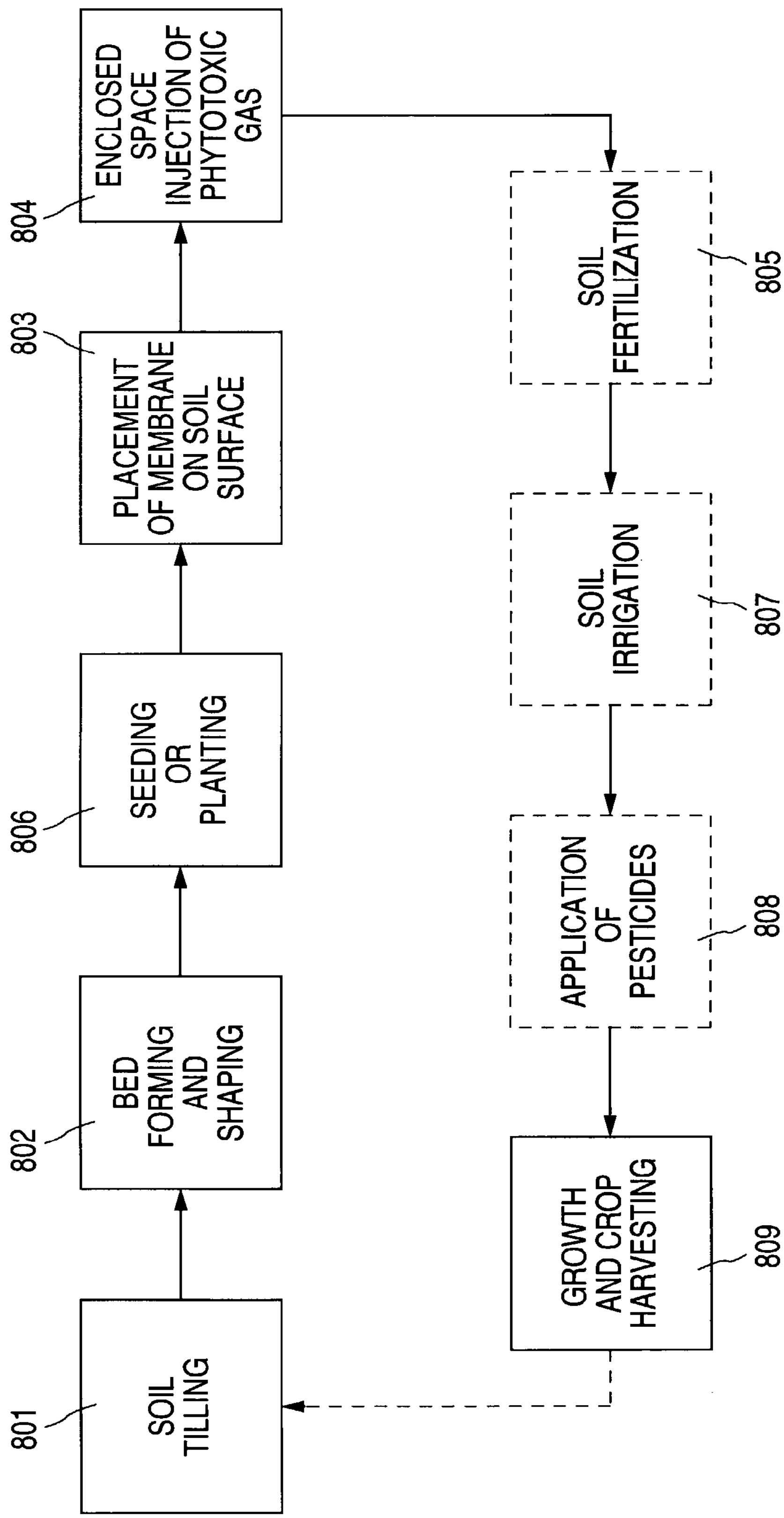
SOIL IRRIGATION
807
GROWTH AND CROP HARVESTING
809
SOIL FERTILIZATION
805

FIG. 7B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SOIL FERTILIZATION
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SOIL IRRIGATION
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APPLICATION OF PESTICIDES
809
GROWTH AND CROP HARVESTING

FIG. 7C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/01831

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) :A01B 79/00; A01G 29/00
US CL :47/58, 48.5
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 47/58, 48.5, 1.01R, DIG.10, 57.5; 111/118, 120; 405/128, 258

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
BRS TEXT SEARCH

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,464,457 A (WINSTON et al.) 7 November 1995 (07.11.95), whole document.	1-41,43,44 46-48
Y	US 4,538,531 A (WONG) 3 September 1985 (03.09.85), whole document.	1-51
Y	US 5,246,309 A (HOBBY) 21 September 1993 (21.09.93), whole document.	40-48,51
Y	US 3,413,940 A (VISSERS) 3 December 1968 (03.12.68), whole document.	40-48,51
Y	US 5,269,943 A (WICKRAMANAYAKE) 14 December 1993 (14.12.93), whole document.	1-39,49,50
Y	US 4,978,508 A (HANSEN et al.) 18 December 1990 (18.12.90), whole document.	40-51

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 APRIL 2001	22 June 2001

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	SON T. NGUYEN
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/01831

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,053,140 A (HURST) 01 October 1991 (01.10.91), whole document.	1-51